

RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF LITHIUM HYDRIDE
AS A HIGH-TEMPERATURE INTERNAL COOLANT

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PRELIMINARY INVESTIGATION OF LITHIUM HYDRIDE
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SUMMARY

Hemispherical and conical stainless-steel shell models containing measured amounts of lithium hydride were tested at stagnation temperatures up to $4,000^{\circ}$ F in a Mach number 2 ceramic-heated jet at the Langley Aeronautical Laboratory to determine the cooling effect of the endothermic decomposition of lithium hydride in the interior of the models. Results of these tests indicate that lithium hydride shows promise as a chemical coolant. No serious handling difficulties were experienced as a result of the reactivity of lithium hydride at room temperature.

INTRODUCTION

A possible solution to the aerodynamic heating problem of long-range missiles is the use of high-drag configurations made of material having a high heat capacity. One of the principal difficulties of this solution is finding a material capable of absorbing the large amounts of heat transferred to the missile without requiring prohibitive amounts of weight.

Energies of dissociation of lithium hydride, given in references 1 and 2, and the heat-input analysis for reentry of long-range ballistic missiles in reference 3 indicate that lithium hydride may be practical as a coolant for hypersonic reentry noses. The dissociation of lithium hydride absorbs 0.75 times as much heat as the vaporization of an equal weight of lithium metal, 4.00 times as much as sodium metal, and 6.9 times as much as water at a pressure of 1 atmosphere.

Lithium hydride is a commercially available white powder having a low density and high reactivity in air. It decomposes endothermically to liberate hydrogen gas and liquid lithium metal. Lithium hydride reacts slowly with air at room temperature and must be stored in airtight containers. The reaction is too slow, however, to cause appreciable

deterioration while transferring the lithium hydride from the container to the models. The only other precaution observed was to keep the lithium hydride away from moisture.

The purpose of this investigation was to observe the behavior of hypersonic reentry nose shapes with lithium hydride as coolant at temperatures up to $4,000^{\circ}$ F in a Mach number 2 ceramic-heated jet and to compare the survival times and the temperatures of the cooled noses with similar uncooled shapes.

Although the testing program for high-efficiency internal coolants is incomplete, the results of these preliminary tests are considered to be of sufficient interest to warrant publication.

MODELS AND TESTS

Four models were tested in this investigation, two models being cone-cylinder shells and two, hemisphere-cylinder shells. One model of each shape was tested with coolant and the other without coolant. Figure 1 shows the configurations of the cooled models.

The models were constructed of type 416 stainless steel and had a diameter of $5/8$ inch. Table I gives the other specifications of the models. The skin thicknesses of the models were varied to give the cooled models approximately the same total weight as the uncooled models and to compensate for the greater heating rates experienced by the cone cylinders.

The models were tested at temperatures up to $4,000^{\circ}$ F in the laboratory-scale Mach number 2 ceramic-heated jet, a description of which is found in reference 4.

The lithium hydride used as the coolant was commercially pure No. 30 mesh powder.

Instrumentation of the models was accomplished with No. 30 gage chromel-alumel thermocouples placed on the center of the inside front wall of each model. Observations of the tests were recorded on 16-millimeter Kodachrome film.

DISCUSSION

The heat absorbed by the decomposition of 1 pound of lithium hydride is approximately 6,900 Btu. The temperature of this decomposition is

about 1,500° F. The decomposition products are hydrogen gas and liquid lithium metal. In order to gain the maximum cooling effect, this decomposition must take place in the absence of oxygen to prevent oxidation of the lithium and the hydrogen.

All four models tested ignited or burned before the end of the runs. The cone-cylinder models burned completely through, while the hemisphere cylinders were removed from the jet before destruction was complete.

Figure 2 shows the variation with time of the inside front wall temperatures of the cone-cylinders and the hemisphere-cylinders. The irregularity of the curves for both cooled models is thought to be due to the agitation of the coolant by the evolving hydrogen gas. The thermocouple failed at 1.3 seconds in the cooled cone-cylinder model (fig. 2(a)). The peak on this curve coincides with the initial burning away of the tip. The dashed line is the estimated temperature rise to the ignition temperature. The star on the dashed line represents the estimated inside temperature at the time at which the final ignition began. The solid horizontal line in figure 2 represents the decomposition temperature of lithium hydride. It is apparent from the figure that the initial heating rate is greater for the cooled than for the uncooled models. This is due to the variation in front wall thicknesses. The rapid temperature rise at the end of each run is due to the heat input of the surface ignition.

The uncooled cone-cylinder (fig. 2(a)) rose to its ignition temperature at 1.0 second and burned vigorously until it was destroyed. The cooled cone-cylinder began burning at 0.9 second and burning stopped at 1.0 second, when the tip of the cone was blunted. No further change was noted in the cooled model until 2.3 seconds, when ignition commenced again and the model burned to destruction. Figure 3 shows the two models at 1.0 and 1.5 seconds. The slight blunting of the tip of the cooled model may be seen in the photograph at 1.5 seconds. Apparently, the heating rate at the point of the cone was too great for the coolant to overcome.

The time required for ignition of the uncooled hemisphere-cylinder was 5.8 seconds. That for the cooled model was 7.8 seconds, figure 4 shows both models at the ignition time of the uncooled models. (See fig. 2(b).) The cooled model was examined after the test, and a white solid was found in the back of the model. This solid was not in contact with the face of the model. A small amount of lithium metal was found in the front of the model. The white solid was found to be a mixture of lithium oxide and lithium hydride. The mixture was analysed for lithium content, and the equivalent weight of lithium hydride was determined. This analysis showed that 0.0014 pound of the original 0.0016 pound of lithium hydride did not decompose, but remained in the model. Thus, 0.0002 pound of the coolant was utilized. This amount of lithium hydride will absorb 1.5 Btu on decomposition. The vaporization of an amount of

water equal to the original amount of lithium hydride will absorb 1.6 Btu. The limiting factor in the utilization of the potential cooling effect of lithium hydride seems to be the quality of the thermal contact between the lithium hydride and the wall to be cooled.

CONCLUDING REMARKS

A preliminary investigation of the cooling effect of lithium hydride indicates that a substantial increase with no sacrifice in weight may be obtained in the life of hypersonic reentry nose configurations subjected to temperatures up to 4,000° F in a Mach number 2 ceramic-heated jet. Although only 23.2 percent of the potential heat of decomposition was realized, the heat absorbed by the lithium hydride was about the same as that which would be absorbed by an equal weight of water, assuming 100 percent efficiency of a water-cooling system.

The limiting factor in the utilization of the potential cooling effect of lithium hydride seems to be the quality of the thermal contact between the lithium hydride and the wall to be cooled. In these tests, the greater part of the coolant adhered to the rear wall and contributed little to cooling. The efficiency of the system may be increased by the use of a feeding system, such as a spring-loaded piston, to insure adherence of the lithium hydride to the front wall. Replacing the air on the inside of the cooled models with an inert gas previous to testing will prevent oxidation of the lithium hydride and further increase efficiency.

Lithium hydride reacts slowly with air at room temperature and must be stored in airtight containers. The reaction is too slow, however, to cause appreciable deterioration while transferring the lithium hydride from the container to the models. The only other precaution observed was to keep the lithium hydride away from moisture.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 31, 1957.

REFERENCES

1. Gibb, Thomas R. P., Jr., and Messer, C. E.: A Survey Report on Lithium Hydride. A.E.C. Rep. No. NYO-3957, Lithium Corp. of America, Inc. (Minneapolis, Minn.).
2. Anon.: Chemical and Physical Properties of Lithium Compounds. Foote Mineral Company (Philadelphia), Jan. 1957.
3. Allen, H. Julian, and Eggers, A. J., Jr.: A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds. NACA RM A53D28, 1953.
4. Purser, Paul E., and Hopko, Russell N.: Exploratory Materials and Missile-Nose-Shape Tests in a 4,000° F Supersonic Air Jet. NACA RM L56J09, 1956.

TABLE I.- DIMENSIONS AND WEIGHTS OF MODELS AND COOLANTS

Model number	Configuration	Wall thickness, in.	Model weight, lb	Coolant weight, lb
1	45° half-angle cone-cylinder shell	0.059	0.042	-----
2	45° half-angle cone-cylinder shell	0.029	0.040	0.0017
3	Hemisphere-cylinder shell	0.197	0.044	-----
4	Hemisphere-cylinder shell	0.120	0.042	0.0016

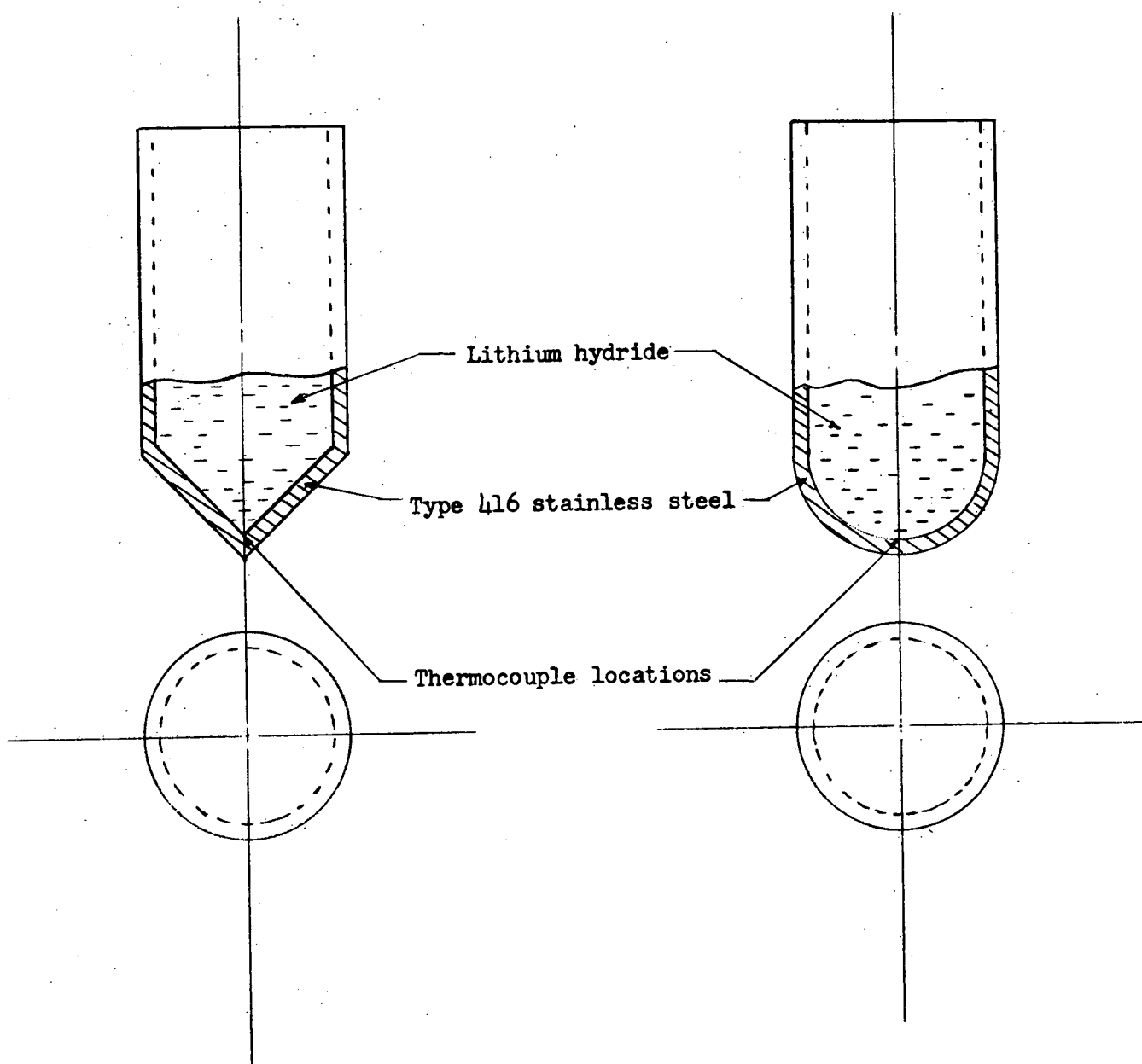
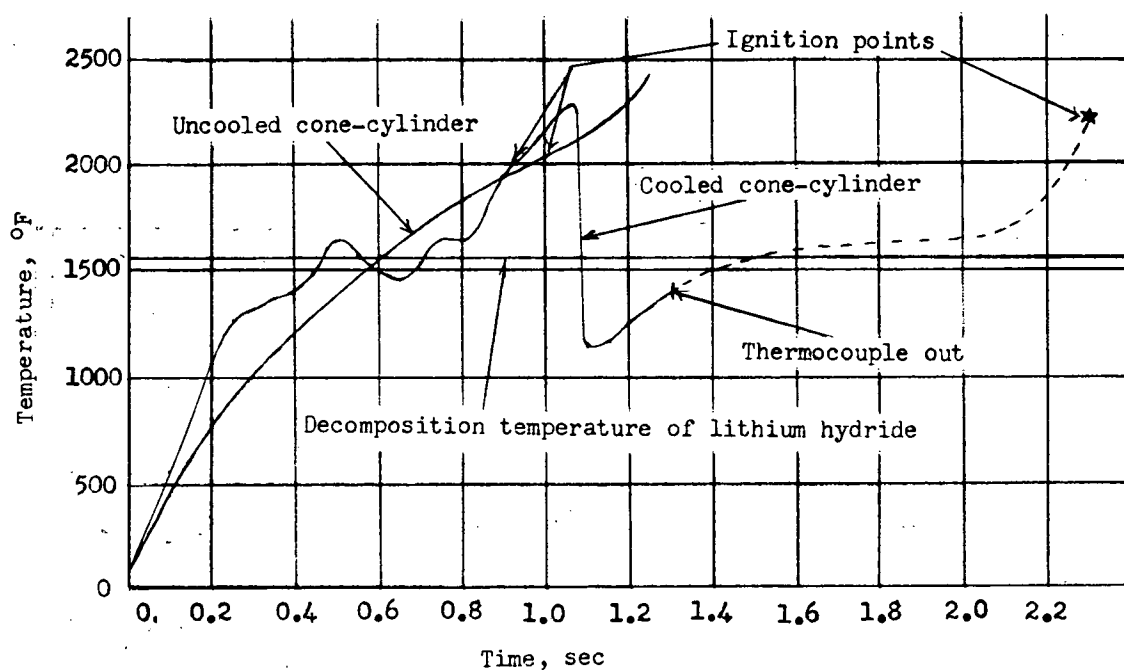
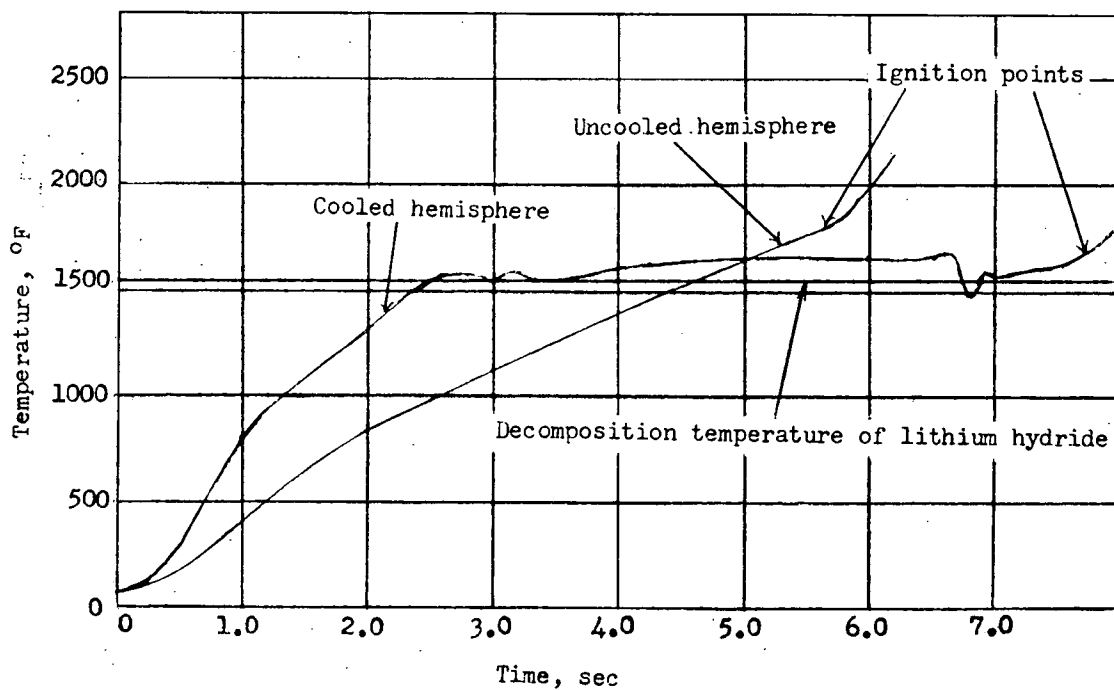


Figure 1.- Hypersonic missile configurations with lithium hydride coolant.

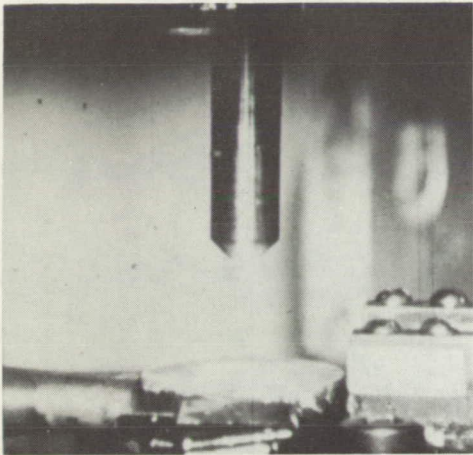


(a) Cone-cylinders.

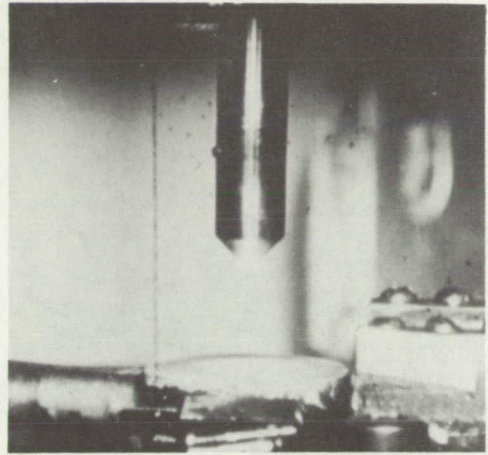


(b) Hemisphere-cylinders.

Figure 2.- Temperature time histories of cooled and uncooled models.



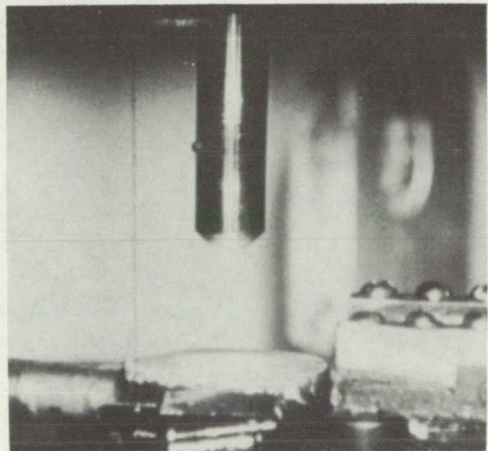
Uncooled model; 1.0 second



Cooled model; 1.0 second



Uncooled model; 1.5 seconds

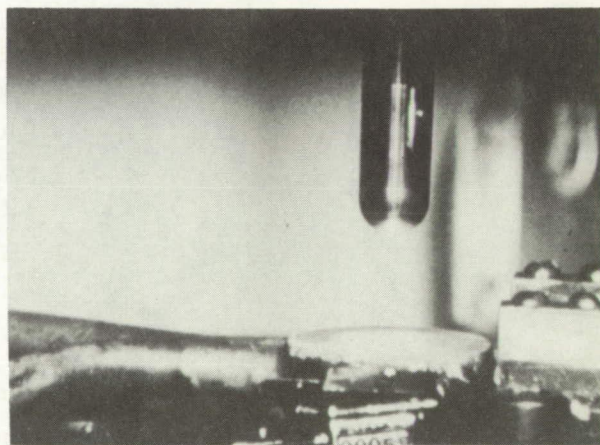


Cooled model; 1.5 seconds

Figure 3.- Cooled and uncooled cone-cylinders. L-57-1606



Uncooled model; 5.9 seconds



Cooled model; 5.9 seconds

Figure 4.- Cooled and uncooled hemisphere-cylinders. L-57-1607